MONITORING HEART RATE VARIABILITY AS A BIOMARKER OF FATIGUE IN YOUNG ATHLETES

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ABSTRACT

Purpose: Many high performance and especially top athletes are still at risk or suffer from total fatigue. Therefore, sports science seeks to develop an objective, sensitive and reliable method of early diagnosis of this fatigue (e.g. heart rate variability – HRV as a modern objective method). The aim of the study was to evaluate whether the HRV monitoring could be a complementary diagnostic tool for overreaching / overtraining in young athletes. Already introduced "classical" indicators of HRV, such as spectral performance and its density in the established frequency ranges, are a part of athlete monitoring in the scope of overreaching prevention We were monitoring the heart rate variability parameters at three different phases of the year-long training cycle and to find out whether in one of these phases we could find athletes showing symptoms of overreaching.
Methods: 48 young athletes (33 boys 14.8 ± 1.5 years, 15 girls 14.9 ± 1.7 years) were involved in the study, consisting of 38 boys and 10 girls. There were 15 swimmers (with training volume 9x 1.5–2 hours a week), 12 artistic gymnasts (with training volume 9x 2–2.5 hours a week) and 21 badminton players (with training volume 4x weekly 1.5–2 hours a week). Monitoring was carried out in athletes in three training periods: at the end of the transition period, at the end of the prepared period, at the end of the competition period. Measurements were carried out in the morning. The DiANS PF8 system was used to measure the heart rate variability, the measurements were performed at five-minute intervals: lying-standing-lying. Time and spectral parameters of HRV were monitored.
Results: Results of HRV in three periods (HR + rMSSD in lying). Boys: HR (61 ± 8, 64 ± 7, 64 ± 8), rMSSD (85 ± 64; 80 ± 54; 88 ± 59), TS (-0.56 ± 1.53; -0.87 ± 1.4; -0.42 ± 1.44). Girls: HR (65 ± 8; 64 ± 7; 65 ± 8), rMSSD (74 ± 37; 79 ± 35; 83 ± 43), TS (-0.58 ± 1.57; -0.72 ± 1.35); -0.18 ± 0.18). Statistically significant differences (at the significance level α = 0.05) among sports were found in Kruskal-Walls ANOVA by Ranks: boys in LF-standing, HF standing, FV, SVB and TS; girls in HF-lying, HF-standing, rMSSD, TP-lying, TP-standing, FV, VA and TS.
Conclusion: Monitoring of heart rate variability seems to be a practical tool for prevention of overtraining even in young age. To monitor heart rate variability, we recommend monitoring these parameters: RR, rMSSD, VA, SVB, TS.

Keywords: heart rate variability; fatigue; training stress; overreaching; overtraining

Introduction

Many factors lead to young athletes suffering from more frequent fatigue or overtraining these days. This is caused by the times we live in and the lifestyle of young athletes. Apart from the training itself, the state of the fatigue is influenced by other stress factors, especially school, activities on social networks and playing telephone, tablet or PC games. One of the most effective natural regeneration means is sleep. Watching the screen until the late hours influences the quality of sleep. Insufficient regeneration becomes evident in bigger and more frequent fatigue during sports training. In order to achieve good quality and effective training it is recommended to monitor the athletes and detect the first effects of overtraining in time, within the frame of the overtraining prevention.

Authors focusing on the overtraining syndrome diagnostics and prevention deal mostly with the adult population. In their article “Overtraining Syndrome” Kreher & Schwartz (2012) provide comprehensive information on terminology, epidemiology, pathophysiology, diagnosis, treatment and prevention. Kreher (2016) complements this with topical knowledge. A similar overview is published by Meeusen, Duclos, Foster, Fry, Gleeson, Nieman…Urhausen, A. (2012) in the article “Prevention, Diagnosis, and Treatment of the Overtraining Syndrome: Joint Consensus Statement of the European College of Sport Science and the American College of Sports Medicine. The authors agree that when diagnosing overreaching and overtraining there should always be a complex approach and there are no clear boundaries between individual phases of overtraining (functional overreaching, nonfunctional overreaching and overtraining syndrome).

Raglin, Sawamura, Aexion, Hassmen, & Kenttä (2000) noted that 35 % of adolescent (13–18 years old) swimmers had been “over trained“ at least once. Mackinon & Hooper (2000) quote that 7–20% of elite athletes may show signs of overtraining at any given time.

One of the still developing methods which is relatively commonly used with top adult athletes is measuring heart rate variability. The development of the method in the sports environment in the Czech Republic can be attributed above all to Stejskal, Šlachta, Elfmark, Salinger, & Gaul-Aláčová (2002). Stejskal (2008) summarised his findings on using heart rate variability (HRV) in sports medicine in Javorka (2008).

Botek, Krejčí & McKune (2017) can see better HRV usage in the frame of individual sports training preparation (running, cycling, swimming, triathlon, etc.). At the same time, they describe using HRV to detect the beginning fatigue or functional overreaching at team sports. The same authors, based on their findings and studies of literature sources, consider log-transformed root mean square of successive R-R intervals (Ln rMSSD) time domain parameter to be a perspective and reliable indicator of the response of the body to the training load, as it, similarly to the high frequency band (HF) spectral indicator, reflects the level of adaptability. Currently it is accepted that power in the high-frequency band (HF, 0.15–0.40 Hz) corresponds to vagal activity, with power in the low-frequency band (LF, 0.04–0.15 Hz) representing some mix of vagal and sympathetic activity.

The purpose of our study was to evaluate whether the HRV monitoring could be a complementary diagnostic tool for young athletes. Another objective was to compare heart rate variability parameters at three different phases of the year-long training cycle and to find out whether the HRV monitoring could be a suitable tool for timely overreaching / overtraining diagnostics at young athletes.

Methods

48 young athletes (15 ± 1.5 years old) from three different sports disciplines (swimming, artistic gymnastics and badminton) took part in the study. There were 15 swimmers (5 boys and 10 girls), 12 artistic gymnasts (only boys) and 21 badminton players (16 boys and 5 girls). Detailed characteristics of the group are listed in Tab. 1.

Table 1 *Group characteristics*

	n	age	weight	height	% body fat
ALL boys	33	14.8 ± 1.5	57.2 ± 12.0	170.5 ± 10.3	14.5 ± 4.2
ALL girls	15	14.9 ± 1.7	56.0 ± 8.0	166 ± 7.8	24.7 ± 2.0
Swimming boys	5	15.2 ± 1.3	61.7 ± 4.8	178.0 ± 5.6	15.5 ± 4.7
Swimming girls	10	15.4 ± 1.3	57.6 ± 6.0	167.8 ± 7.5	25.5 ± 2.1
Gymnastics boys	12	15.1 ± 1.5	53.1 ± 9.4	163.3 ± 8.9	13.1 ± 1.5
Badminton boys	16	14.5 ± 1.4	57.7 ± 13.6	171.7 ± 9.7	16.2 ± 3.6
Badminton girls	5	13.9 ± 1.7	52.0 ± 9.1	162.4 ± 6.9	23.5 ± 1.5

Heart rate variability monitoring was carried out in these phases of the year-long training cycle: at the end of the transition period, at the end of the preparatory period, at the end of the competition period. HRV was recorded three times a week in each period (there are nine records per athlete). Measurements were carried out in the morning under the supervision of the testing person and in quiet training premises. The DiANS PF8 system was used to measure the heart rate variability, the system records beat after beat with high accuracy.

The measurements themselves were carried out in two positions as follows:

LYING 5 min – STANDING 5 min – LYING5 min

We monitored these time-domain and SA HRV parameters: HR, very low frequency band (VLF), LF, HF, total power (TP), LF/HF, VLF/HF, VLF/LF, RR or NN (normal to normal), square root of the mean of the squares of the successive differences between adjacent NN intervals (rMSSD). We used for evaluating these complex indexes spectral analysis heart rate variability (SA HRV): functional age (FA), sympathovagal balance (SVB), vagal activity (VA), total score (TS).

We set up borders for assumed overreaching: lower TS: less than -1.5 and. higher value of FA: over 5 years than calendar age.

Results

The two tables below present the basic results of the measured data for the individual parameters in the three phases of the year-long training of boys and girls. Tab. 2 lists the basic HRV parameters and Tab. 3 shows the complex indexes SA HRV.

Table 2 *Basic HRV parameters (median ± SD)*

	Training period	**HR**	**RR**	**RR**	**rMSSD**	**rMSSD**	**LF**	**LH**	**HF**	**HF**
			lying	**standing**	**lying**	**standing**	**lying**	**standing**	**lying**	**standing**
BOYS	I	61 ± 8	0.98 ± 0.12	0.61 ± 0.08	85 ± 64	16 ± 15	856 ± 1127	478 ± 456	2171 ± 4361	181 ± 287
(n=33)	II	64 ± 7	0.94 ± 0.11	0.61 ± 0.07	80 ± 54	19 ± 20	754 ± 735	562 ± 631	1679 ± 3507	196 ± 187
	III	64 ± 8	0.94 ± 0.12	0.64 ± 0.08	88 ± 59	28 ± 15	737 ± 884	602 ± 630	1984 ± 3089	258 ± 284
GIRLS	I	65 ± 8	0.94 ± 0.12	0.58 ± 0.11	74 ± 37	14 ± 27	708 ± 337	442 ± 1570	1578 ± 2411	114 ± 997
(n=15)	II	64 ± 7	0.94 ± 0.10	0.60 ± 0.07	79 ± 35	14 ± 12	640 ± 1203	453 ± 1058	2037 ± 2032	172 ± 319
	III	65 ± 8	0.92 ± 0.13	0.62 ± 0.09	83 ± 43	21 ± 26	642 ± 623	687 ± 845	1994 ± 2235	222 ± 1257

Table 3 *Complex indexes SA HRV (median ± SD)*

sport	Training period	FV	SVB	VA	TS
BOYS	I	17.1 ± 5.7	-2.05 ± 2.05	0.02 ± 1.60	-0.56 ± 1.53
(n=33)	II	18.9 ± 5.3	-2.12 ± 1.48	-0.39 ± 1.41	-0.87 ± 1.40
	III	17.0 ± 5.8	-1.39 ± 1.51	0.298 ± 1.59	-0.42 ± 1.44
GIRLS	I	19.1 ± 5.7	-0.92 ± 1.67	-0.26 ± 1.71	-0.58 ± 1.57
(n=15)	II	18.7 ± 4.9	-1.35 ± 1.17	-0.30 ± 1.46	-0.72 ± 1.35
	III	16.9 ± 4.6	-1.23 ± 1.14	0.28 ± 1.31	-0.18 ± 1.18

The statistical differences (Kruskal-Wallis test) between individual sports are listed in Tab. 4, separately for boys and girls. For boys we found statistical differences for these parameters: LF-standing, HF-standing, FA, SVB, TS. In Fig. 1-2 we can see the differences for parameters SVB and TS. For girls we noted statistically significant differences for the following parameters: MSSD-standing, HF-standing, HF-lying, TP-standing, TP-laying, FA, VA, TS. Fig. 3–4 show these differences using box plots for VA and TS.

Table 4 *Statistically significant differences between individual sports*: *boys: badminton, gymnastics, swimming and girls (badminton and swimming), at the significance level* α *= 0.05. Presented results are averages from all3 monitored training periods*

HRV parameter	Boys (N=99)	Girls (N=45)
RR-lying	p = 0.3870	p = 0.1626
RR-standing	p = 0.1418	p = 0.1120
VLF – lying	p = 0.2293	p = 0.5002
VLF - standing	P = 0.2040	p = 0.2019
LF-lying	p = 0.1510	p = 1.000
LF-standing	p = 0.0375	p = 0.4554
HF-lying	p = 0.4741	p = 0.0123
HF-standing	p = 0.0362	p = 0.0009
MSSD-lying	p = 0.7348	p = 0.1699
MSSD-standing	p = 0.0740	p = 0.0208
TP-lying	p = 0.8583	p = 0.0183
TP-standing	p = 0.1144	p = 0.0572
FV	p = 0.0238	p = 0.0013
VA	p = 0.0793	p = 0.0021
SVB	p = 0.0005	p = 0.3602
TS	p = 0.0211	p = 0.0048

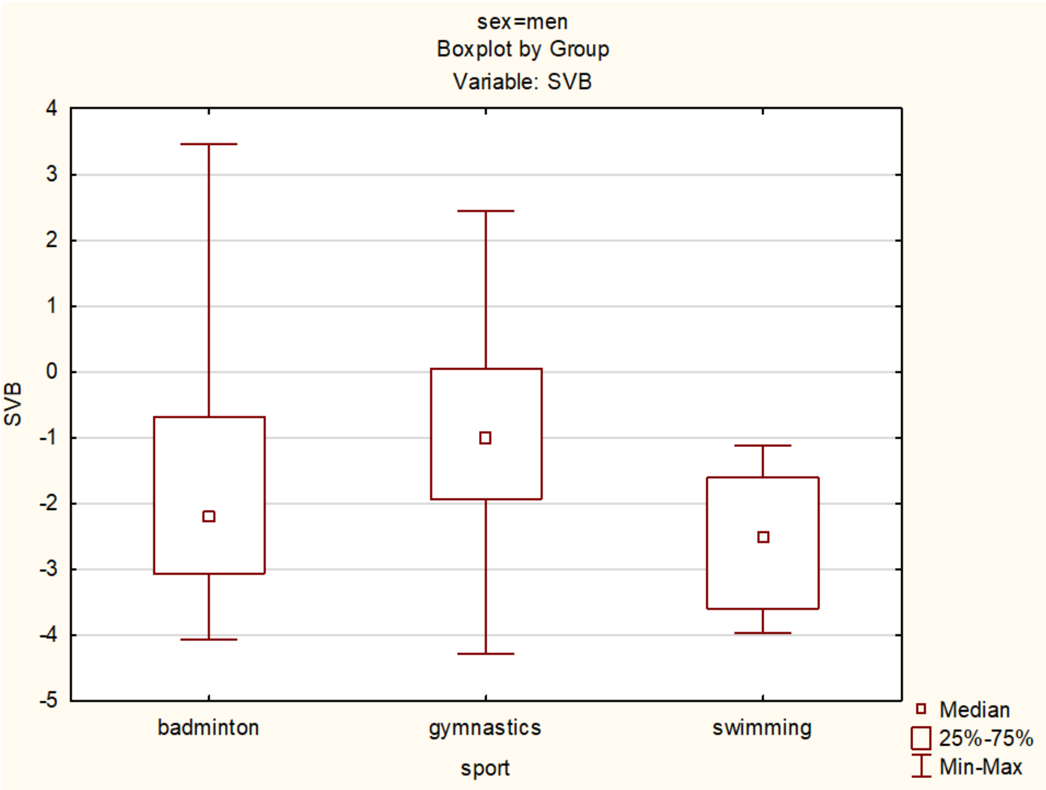

Figure 1 *Differences of SVB among sports in boys*

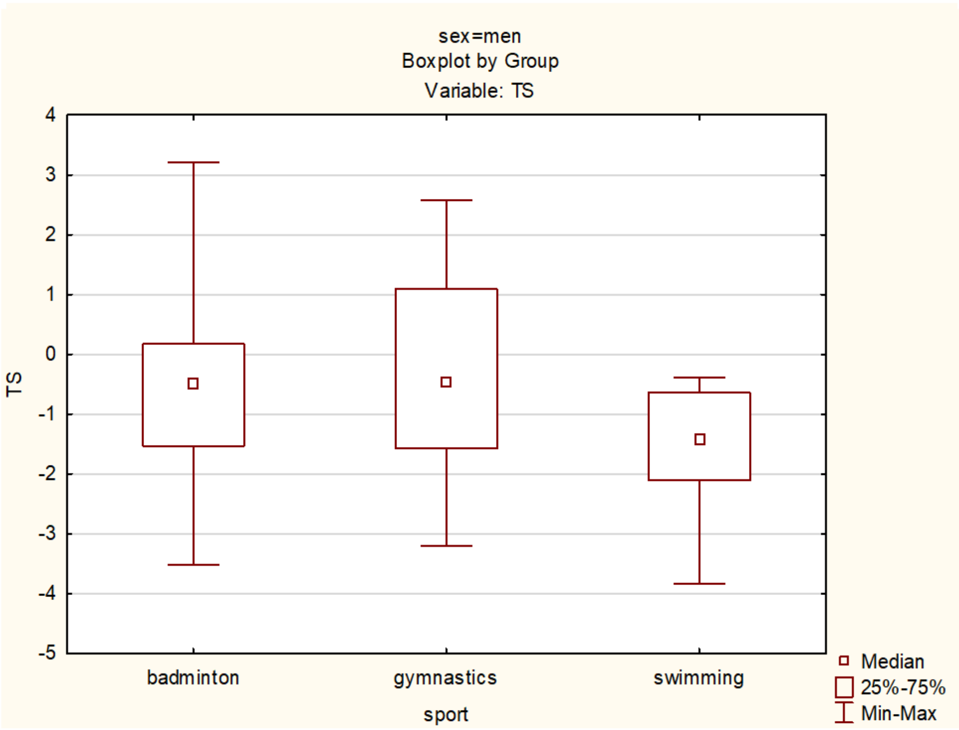

Figure 2 *Differences of TS among sports in boys*

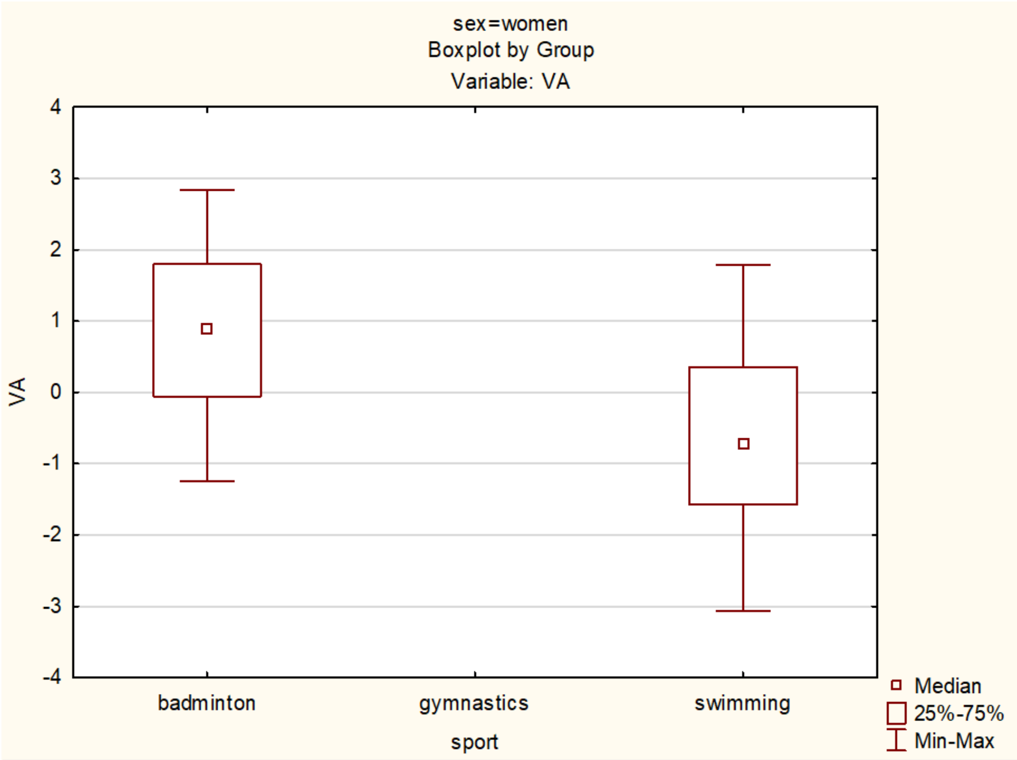

Figure 3 *Differences of VA between badminton and swimming in girls*

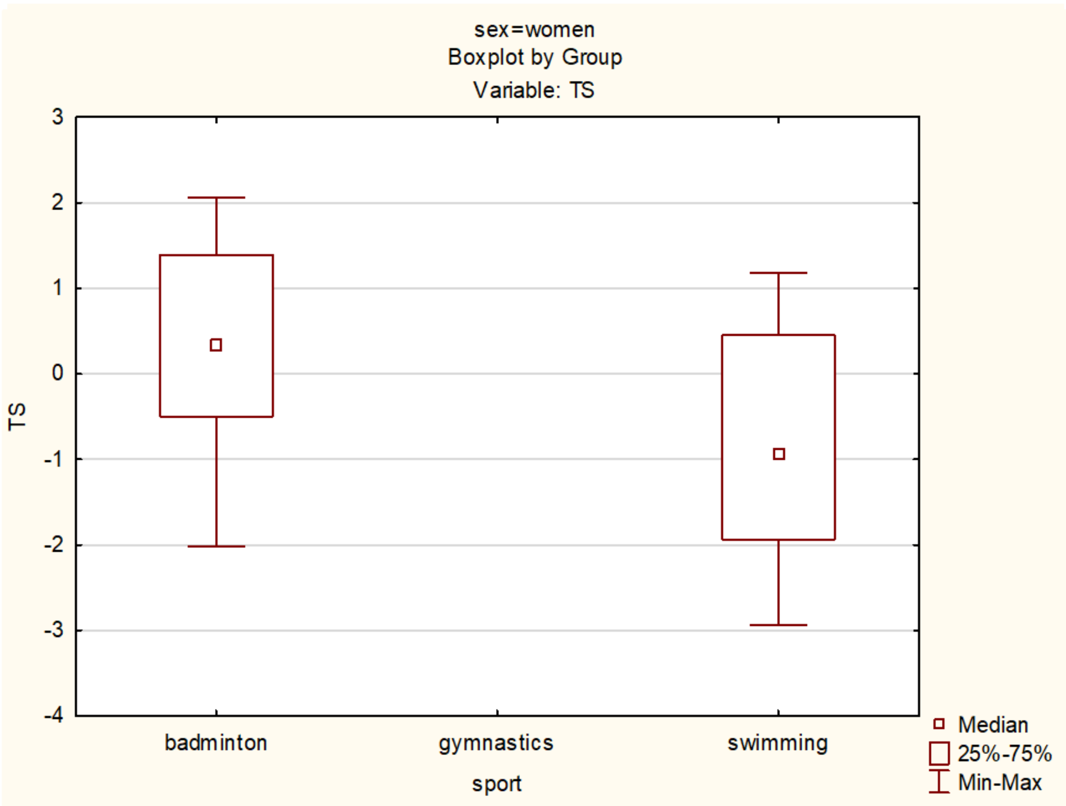

Figure 4 *Differences of TS between badminton and swimming in girls*

Out of a total of 48 young athletes, 4 individuals (2 swimmers, 1 gymnast, 1 badminton player) were found to have a higher overreaching (lower TS: less than -1.5). Higher value of functional age (over 5 years than calendar age) were detected in 7 individuals (5 swimmers, 1 gymnast, 1 badminton player) repetitively.

Discussion

Heart rate variability monitoring at the target group did not encounter any problems. Young athletes quickly understood how the measurements would be carried out and had no problems staying inactive during the resting measurements. Checks during the measurements reassured us that the data could not be distorted at his phase.

When comparing the three phases of the year-long training we didn't find the statistically significant differences in boys and girls (tab. 2 and 3). But the results show that parameters are lower at the end of the transition period than at the end of the preparatory and competition period. Very interesting is evaluation intraindividual differences, we found change for the better or the worse. We recommend more case history and qualitative studies for future.

When comparing the three sports (Kruskal-Wallis test) we found the statistically significant differences for the summative indexes TS for both genders, SVB for boys and VA for girls. As it is clear from the findings listed above, the highest values we found at the badminton players, followed by artistic gymnastics and the lowest values of the parameters were measured at the swimmers. This corresponds to the fact that badminton players have the lowest training loads and on the contrary the highest loads are there for artistic gymnasts and swimmers.

The Tab. 5 compares our measurements with the norm for 12-17-year-old athletes for 10 min lying as published by Sharma, Subramanian, Arunachalam, & Rajendran (2015).

Table 5 *Comparison of our results with the Sharma, Subramanian, Arunachalam, & Rajendran (2015) and Novotný & Novotná (2008) results*

Parameters	**Athletes 5 min lying (our results)**		**Athletes (12–17 years) 10 min lying (Sharma et al. 2015)**		**Nonathletes (13–15 years) 5 min lying (Novotný & Novotná 2008)**	
	girls	boys	girls	boys	girls	boys
HR			80.67	72.27	76.4	79.6
SDNN (ms)			113.00	94.20	70.0	70.0
rMSSD (ms)	86.9	108.6	94.9	100.3		
VLF (ms^2)					3659	2365
LF (ms^2)	640	1274	1465	1211	686	793
HF (ms^2)	1578	2171	2409	2219	1033	1553
Total Power (ms^2)	3717	5797	5202	5273	6639	6274
LF/HF ratio	0.40	0.59	0.63	0.59		

Fortes, da Costa, Paes, do Nascimento Júnior, Fiorese, & Ferreira (2017) monitored HRV parameters at 15–16 year-old swimmers lnRMSSD (ms) 3.6 ± 0.5) mean (SD) – 10 min sitting. HRV measurements at adolescent swimmers (15.5 ± 0.9 years) were also carried out by Vacher, Nicolas & Mourot (2016) – 8 min lying, 8 min standing. rMSSD 76 ± 43 in supine posture and rMSSD 47 ± 33 in standing posture.

For further similar studies we recommend the following: When monitoring the HRV the load intensity should also be recorded (monitoring SF or Borg) and the obtained values should be compared with other diagnostic methods for fatigue monitoring (POMS questionnaire, sleep, immunology markers from saliva / blood, etc.). Only a complex monitoring and analysis have a greater potential to detect athletes who are at risk of overreaching/overtraining.

Conclusion

Based on the obtained data we can claim that HRV monitoring seems to be a suitable tool for overtraining prevention even for young athletes. We believe that measurement can detect the beginning phase of overtraining. Based on the obtained data the following parameters for HRV monitoring are suitable: VA, SVB, TS. For training practice, we also recommend using parameters which are simpler to interpret, such as FUNCTIONAL AGE, as these are more understandable both for trainers and for the young athletes themselves. In order to use this tool as of then as possible by athletes, there is a tendency to shorten the measuring times due to time reasons.

Acknowledgements

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